# Multimodal Guidance System for Improving Manual Skills in Disabled People

Mario Covarrubias, Elia Gatti, Alessandro Mansutti, Monica Bordegoni, and Umberto Cugini

Politecnico di Milano, Dipartimento di Meccanica
Via G. La Masa, 1, 20146 Milano, Italy
{mario.covarrubias,elia.gatti,alessandro.mansutti}@mail.polimi.it,
{monica.bordegoni,umberto.cugini}@polimi.it

**Abstract.** The paper describes a multimodal guidance system whose aim is to improve manual skills of people with specific disorders, such as Down syndrome, mental retardation, blind, autistic, etc. The multimodal guidance system provides assistance in the execution of 2D tasks as for example: sketching, hatching and cutting operations through haptic and sound interactions. The haptic technology provides the virtual path of 2D shapes through the point-based approach, while sound technology provides some audio feedback inputs about his or her actions while performing a manual task as for example: start and/or finish an sketch; some alarms related to the hand's velocity while sketching and filling or cutting operations. Unskilled people use these interfaces in their educational environment.

**Keywords:** Haptic Guidance, Unskilled People, Sound Interaction.

## 1 Introduction

The multimodal system presented in this paper, consisting in a combination of haptic and sound technologies, aims to be a step forward in the field of multimodal devices for supporting unskilled people to improve their skills and in the assessment of manual activities. Sketching, hatching and cutting tasks are assisted through the haptic guidance device. A Magnetic Geometry Effect assist the users hand movement, which is a sort of magnet or spring effect attracting the hand towards the ideal path. The drawn shape can also be physically produced as a piece of polystyrene foam. The cutting operation is performed by using a hot wire tool, which is linked to the haptic device. In addition, several sound metaphors are explored. These sounds are used to give information related to the starting and/or finishing of an activity (e.g. Sound A means, starting to cut while sound B means Stop the cutting activity and Sound C, can be used to indicate that the velocity in the cutting task is the most performing, etc.)

The objective of the multimodal system is to experiment a new tool that allows unskilled people to perform the assessment of manual skills in an intuitive, natural and easy manner. This group of people have demonstrated that with

K. Miesenberger et al. (Eds.): ICCHP 2012, Part I, LNCS 7382, pp. 227–234, 2012.

early intervention programs, their possibilities of having a better life are growing as well. Unfortunately today practice to control the motion control and skill improvements need to be done with continuous assistance given by care assistants, so greatly limiting the possibility to exploit the great potential that those people have. However, there is still much more opportunity for developing tools to help and support them for improving both, their productivity and independence in the workplace. This can be done, by providing tools to employers and employees to assist them to maximize the operational capacity. The multimodal system is designed as a tool that supports manipulation and actions needing a very limited support provided by care assistants, for ensuring the integration and independence in the workforce.

## 2 Related Work

The research concerning haptic technology has increased rapidly in the last few years, and results have shown the significant role that haptic feedback plays in several fields, including rehabilitation. The interaction is enriched by the use of the sense of touch, so that also visually impaired users can identify virtual objects and perceive their shape and texture. Within the field of virtual reality environments and simulation tools, the sense of touch is provided by haptic interfaces [1]. Haptic interfaces are based on devices that present tactile and force feedback to a human user who is interacting with a simulated object via a computer [2] in order to feel the virtual object properties (i.e., texture, compliance or shape). Examples include devices that provide robotic-assisted repetitive motion [3]. There are, however, very few assisted applications for unskilled people which support them in a specific employment role.

Haptic interface technology can enable individuals who are blind to expand their knowledge by using an artificially made reality built on haptic and audio feedback. Research on the implementation of haptic technologies within Virtual Environments has reported the potential for supporting the development of cognitive models of navigation and spatial knowledge with sighted people [4], [5], [6], [7] and with people who are blind as well [8]. Audio feedbacks have been used coupled to haptic feedback in several fields. In [9] for example have been used to train ophthalmic surgeon on complex optical operation.

We have used the Phantom Desktop device that is available in our laboratory in order to show and prove the concept of the multimodal guidance system. In fact, at the current development stage, the system is a prototype that requires to be engineered in order to built up a very low cost system; a goal that appear very realistic. However, we have planned in the engineering process to integrate the force feedback directly in our guidance system instead of using a commercial phantom device, taking into account several previous work [10], [11] in which the force feedback has been integrated directly into the pantograph mechanism. The guidance haptic device concept has been described in [12]. This paper focuses on the multimodal approach through the sound metaphors and the results of testing the first prototype.

## 3 System Description

The multimodal guidance system allows the initial definition of a set of geometric shapes that the users will draw, and physically produce thanks to the cutting system in an assisted way. Figure 1 provides a schematic view of the system's architecture. The shapes are initially generated through the use of a generic CAD tool. The shapes are saved in the VRML format, which is a standard file format for representing 3-dimensional interactive vector graphics. This file includes the IndexedFace set list, which represents the 3D shape formed by constructing faces (polygons), and the Coordinate point list, which contains the coordinate of each single node that defines the 3D vertices of the shape. Finally, these data are imported in the H3DAPI software that is used for rendering the haptic guiding path, on the basis of the geometry of the shape.

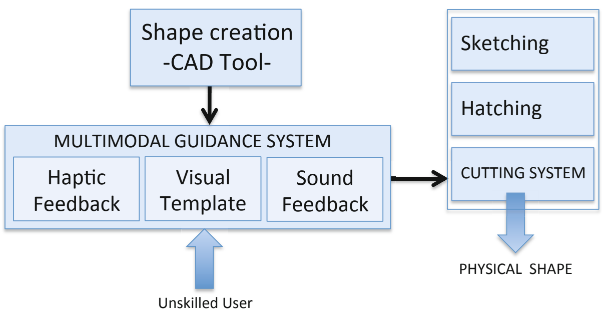


**Fig. 1.** Multimodal guidance system architecture

This software was chosen because is an open source platform that allows to handle both graphics and haptic data. The software also allows to easily manage the Magnetic Surface constraint, which provides a force on the haptic device based on a given distance from a virtual surface. In this way, a snap constraint is applied allowing to control and vary as needed the stiffness and damping constraints. The snap distance is a parameter that defines the outward distance for the application of the attracting effect.

## 4 The Concept from the Disabled People Side

Figure 2 provides the isometric view of both, the CAD concept and the real prototype of the multimodal system seen from the users side. The user is sitting in front of the multimodal system as can be seen from Figure 2-**a**, and then by handling the stylus (3) tries to follow the physical template (1) in order to perform the 2D drafting tasks. This task is driven under the operators movement and assisted by the Magnetic Geometry Effect (MGE). When this option is enabled, a spring force tries to pull the tip of the stylus (3) of the haptic device towards the virtual path. In fact, this effect is used in order to assist the users

hand (Figure 2-**b**, Figure 2-**c** and Figure 2-**d**). While user follows the 2D template (1) by using the haptic guidance, the wire tool (6) when activated will cut the polystyrene foam (2). Figure 2-**e** shows the physical prototype and the users hand holding the tool.

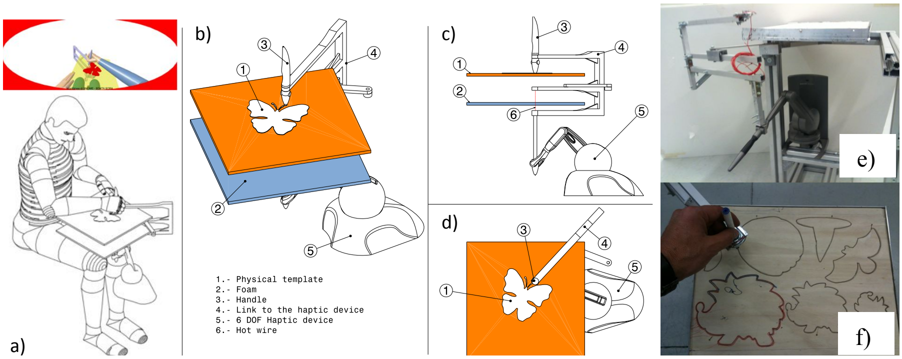


**Fig. 2.** The concept from the disable people side

The lengths of the links in the Phantom device (1) determine the mechanisms kinematic properties, such as workspace and manipulability.

## 5 The Concept from the Care Assistants Side

We have designed a Graphic User Interface in order to involve teachers and care assistants during the test phase. In this way, we are also providing some training for the use of the system. Figure 3-**a** shows the teacher while using the GUI interface; Figure 3-**b** shows the first screen asking for the shape selection. We have designed simple and complex shapes, i.e. circle, triangle, hexagon, rectangle, spiral, porcupin, bat, etc. Figure 3-**c** shows the screen that has been selected by the teacher/care assistant in order to have the visual feedback. If the F1 key is pressed, a circle is activated in order to ask the unskilled user to perform the sketch operation, if the F2 key is pressed a triangle is activated and so on. This graphical interface allows the teachers the possibility to switch between different shapes and set the modality task that has to be performed, as sketching, hatching or cutting task.

Figures 3-**d** and 3-**e** show the screen that has been used during the test of the multimodal device. While the unskilled people are the end-users of the technology, it is possible to consider a more person-centered approach to both the evaluation of the multimodal guidance and to the research.

## 6 Evaluation of the System by the Care Assistants

In our study we have used a qualitative approach to evaluate the ergonomics of the system, and to reach the overall impression from users and their assistant.

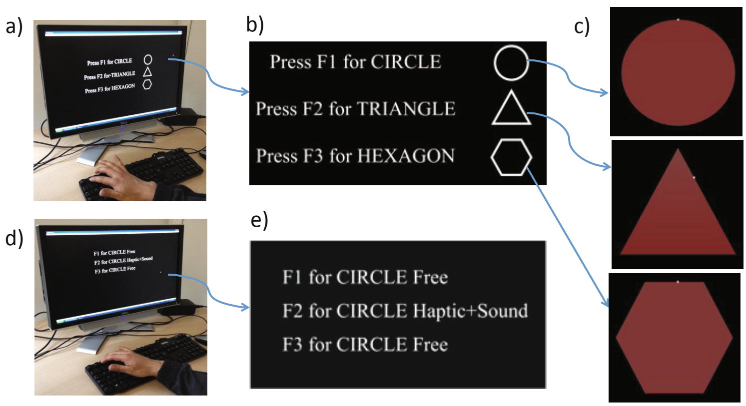


**Fig. 3.** The concept from the teacher and care assistant side

We decided to interpret data as complementary to the obtained quantitative data. Table 1 shows the qualitative observation of the users.

One of the major problems of the qualitative analysis is the challenging validation of the theories that rise from the recorded impressions. Nevertheless, those kind of information could be an important index regarding the well-functioning of the system and the possible further improvement. The overall impression is positive. The qualitative data have been obtained by two ways. For points 1,4 and 5 reported in Table 1 we directly asked to users or to the educators opinions and suggestions. For the points 2 and 3 we obtained data observing the users behavior. The system helping effect has been found very interesting and rewarding by the users, that have been able to focus their attention on the task.

## 7 Sound Interaction

The sound feedback of the multimodal haptic device gives the possibility to play metaphoric sounds while the user's interact with the system . These metaphoric sounds provides information to the disable people according to the type of task performed. In fact, once the sound feedback is enabled, the sound feedback gives the following information:

– Metaphoric sound A, if the stylus pen is not located directly on the shape. This sound is a kind of warning alarm and means that the user's pen is located quite far from the haptic shape.
– Metaphoric sound B, is played when the velocity of the stylus pen is higher than an specific value. Also in this case, the sound is rendered as a warning alarm, and is activated when the user's pen goes too fast in the sketching, hatching and cutting tasks.

**Table 1.** Evaluation of the Multimodal Guidance System

| | **Main questions** | **Results** |
|---|---|---|
| Comfort | Is the system comfortable for the users? They can use it in a comfortable position? | All the participants involved into the evaluation have been able to use the system in a comfortable way; the portability and the reduced dimensions allow all the subjects to set their position in the most comfortable way while they performed the task. |
| Interest | Is the system able to interest and to focus the user attention on the task? | For all the participants the system has been a great source of interest. In the evaluation phase, all of them have been able to complete the task without distraction. |
| Usability | Is the system intuitive? | The majority of the subjects started to interact whit the system in a correct way, grasping the stylus and moving it without any instruction. |
| Utility | Is the system useful in the educators opinion? | For all the educators the system constitutes a valid help to their work, interesting and helping subjects in the drawing and coping task. |
| System completeness | Provide the system all the cues needed for a good performance of the task? | In the educators opinion more important forces are needed, depending on the user deficit. Moreover, an interactive and funny interface has been suggested in order to involve more the subjects in the task. |

## 8 User Test

The user test has been performed involving 6 subjects (4 males) aged 18 to 40 years. Down syndrome and mental retardation affected all participants. In this experiment a brief familiarization has been offered to the participants and it has been asked to perform a task that involved a combination of visual, haptic and sound feedback in order to design a circle with 100 mm of radius. Figure 4-**a** shows the tracked motion of an spiral shape without haptic and sound feedback, while Figure 4-**b** shows the tracked motion for the same disable people with the haptic and sound feedback. Figure 4-**c** shows the tracked motion of a circle without haptic and sound feedback while Figure 4-**d** shows the tracked circle with the haptic and sound feedback.

In order to systematically assess the contribution of the haptic and sound feedback we computed the error between the radius of two circles as reported from Figures 4-**e** and 4-**f**. Results showed that the error significantly decreases (Wicloxon rank sum test, $p \ll 0.05$) when subjects were guided. For what concerns the evaluation activities related to the developed prototype of the multimodal guidance system, we have decided to evaluate:

1. The applicability of the multimodal guidance system to the learning environment.
2. Gaining feedback on the development, improvement and overall technical assessment of the multimodal guidance device, and suggesting recommendations for functional changes for subsequent prototypes.

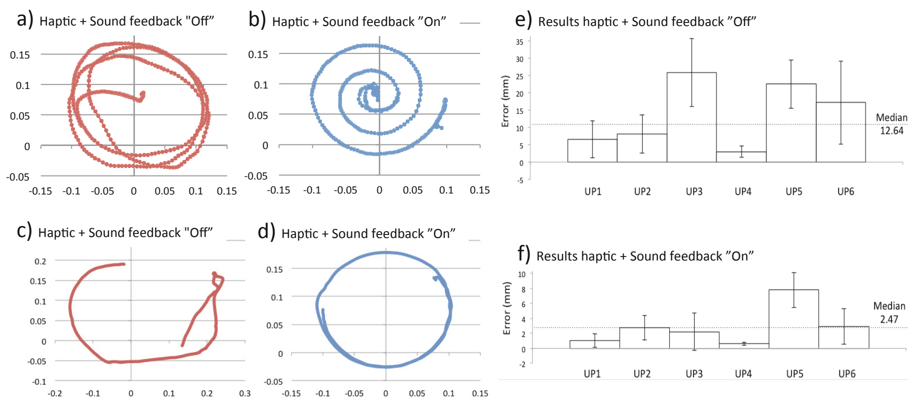


**Fig. 4.** User's test results

## 9 Conclusion

The results of our study showed that the multimodal guidance system help people during manual tasks by means of using haptic and sound technology.

The opportunity to create a haptic system that would make real difference in disable peoples life appeared to be a highly motivating factor. We are currently performing an evaluation with unskilled people in order to measure their learning improvements in 2D operations skills. Results show that the effect of using the haptic cutting system increases the accuracy in the tasks operations. We can resume that the system leads to the satisfaction of the following objectives:

- The force feedback enhances the interaction between the user and the physical template.
- The sound feedback as and additional channel information in order to performing the 2D tasks according with the correct velocity required to sketch, hatch and cut the foam.

**Acknowledgement.** The authors would like to thank all the instructors at Laboratorio Artimedia (Calolziocorte, Italy), Casa Dei Ragazzi Treves De Sanctis O.N.L.U.S., and Centro Diurno Disabili Di Barzan for their support in the preliminary evaluation of the haptic guidance device and for giving us the opportunity to test the system.

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